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PROGRESS REPORT NO. 14

July 1978

EVALUATION OF FRENCH PRESSUREMETER

by

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for

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FEDERAL HIGHWAY ADMINISTRATION
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1. INTRODUCTION

This fourteenth progress report describes the work accomplished during July, 1978. Table 1 lists the work tasks and presents the schedule as revised in July 1978. Task A (in Table 1) having been completed, July was devoted to Task B and C as follows:

Task B: Measurement of in situ horizontal stress

Task C: Interpretation of PAFSOR tests

1) Establishment of in situ soil parameters
2) Analysis of pressuremeter (PAFSOR) test data
3) Literature Survey

2. WORK ACCOMPLISHED AND SUMMARY OF RESULTS

The principal activities during July 1978 are summarized in Table 2 and described more fully below.

Task B: Measurement of In Situ Horizontal Stress

Readings on the three earth pressure cells inserted at El.-80 ft were taken at approximately one week intervals. Figure 1 shows the equilibration rates of the horizontal stress and pore pressure and estimated values of σ_{ho} and u_o based on elastic theory and values of K_o measured in the laboratory. Plans for the removal of the devices have been postponed due to the trend displayed by the sharp (20°) symmetrical cell. At this time, it is impossible to determine whether the recent stress increase is due to a change in the state of stress around the cell or to a zero shift in the transducer. Therefore, the cell will remain in place as long as possible. Based on the latest (1000 hrs) earth pressure cell data, K_o values at El.-80 ft have been revised and are shown in Figure 2. Upon removal of the cells, recalibration of the electrical sensors should assist in selecting final values for each device.

The enlarged tip measuring cell is still defective. The measured value of σ_h decreased continuously throughout the month of July, but the data are not shown in Figure 1 as they are obviously in error (less than 2 ksc).

Task C: Analysis of Pressuremeter (PAFSOR) Test Data

1) Establishment of In Situ Parameters

Dr. Ladd reviewed the field vane, Dutch cone and SHANSEP strengths, results of model footing tests and analyses of the embankment failure. The resulting "final" in situ strength profile is plotted in Figure 3. This profile will be used as the reference strength in Boston Blue Clay at Sta. 246 for stability problems. Figure 3 also shows the field vane strength for comparison purposes.

2) Interpretation and Analysis of Pressuremeter Test

During July, we mainly studied the effect of initial pressure on the parameters derived from the pressuremeter curve. We focused on the 15 PAFSOR tests run at Sta. 246 and defined the start of the test in five different ways:

1) Start of the test on field ($P-\Delta V$) curve
2) Inflection point (as determined by accepted methods)
3) Extended inflection point (as illustrated in Fig. 4)
4) Lower limit of best estimate of σ_{ho}
5) Upper limit of best estimate of σ_{ho}

Figure 4 illustrates each of these "initial" points for a typical PAFSOR pressure-volume ($P-\Delta V$) curve from Sta. 246.

Using these initial points, we determined the following parameters (via the computer program developed for this research):

1) Limit pressure, P_1 (ln and 1/V methods)
2) Undrained Shear strength from empirical correlation

$$c_u = \frac{P_1 - P_o}{6.0} \qquad \text{(Eq. 1)}$$

3) Peak undrained shear strength (ln and subtangent methods)
4) "Residual" undrained shear strength (ln and subtangent methods)
5) Undrained shear modulus at 50% peak shear stress, E_{50}
6) Complete stress-strain curve.

Figures 5 to 11 present most of the results obtained. In Figure 5, the limit pressure (1n method) appears insensitive to the starting point on the P-ΔV curve, as it seldom varies more than 5%. In general, the limit pressure values are very high.

Figure 6 compares the limit pressure as determined by the 1n and inverse methods. As noted in the previous progress report, the Camkometer tests lie on or below the relationship presented by Dr. Jamiolkowski. The limit pressure by the 1n method is 10% or more higher than the limit pressure by the inverse method and their correlation does not appear as uniquely linear, at least at values less than 9 kg/cm^2.

The undrained shear strength based on the empirical relationship:

$$c_u = \frac{P_1 - P_o}{6.0} \qquad \text{(Eq. 1)}$$

and shown in Figure 7 decreases consistently, as expected, as the origin of the P-ΔV field curve is shifted upwards. Differences as large as 30% are observed between the actual "start of test" P_o value and the upper estimate of σ_{ho}. The stength variation with depth is reasonably identified by the PAFSOR tests (at least by this method of interpretation) but the experimental s_u values are still substantially higher than the in situ strength.

Three parameters characterizing a stress-strain curve are: peak shear strength, residual shear strength, and secant modulus at 50% of peak shear stress. Figures 8 to 10 illustrate these parameters: Figure 8 presents peak shear strengths obtained from the maximum slope of the P vs 1n ΔV/V plot. These strengths increase substantially with depth and are extremely sensitive to the origin of the pressure-volume curve. In cases where the slope of the pressure-volume plot increased, (i.e. an inflection point), the computed strength shows a sharp peak. This strength is not considered characteristic of the soil but is probably due to seating problems and/or changes in the strain rate.

The residual shear strengths, shown in Figure 9, correspond to a shear strain on the order of 10% and present a very different profile than that of Figures 7 or 8. The residual

shear strength also depends on the origin of the P-ΔV curve, although to a lesser extent than the peak shear strength. The range in P_o values caused a variation in residual s_u on the order of 25%. Except at great depths, the residual s_u is much higher than the in situ strength.

Figure 10 plots the sensitivity of the clay, defined as the ratio of peak to residual strength. The figure illustrates the increased sensitivity with depth. Salt concentration tests on samples from Sta. 246 supported this conclusion (see Progress Report No. 12).

Figure 11 summarizes the undrained modulus at 50% peak shear stress derived from the PAFSOR tests. The three shallowest tests have low E_{50} values (they also had low P_1 and undrained shear strength values) whereas the other tests exhibit considerable scatter. The modulus can vary by as much as 70% due to changes in P_o. This parameter has not yet been compared to lab values, but using $E_u/s_u=1000$ would give $E_u=500$ kg/cm^2.

3) Literature Review

This month, we reviewed John et al's report on "American Experience with PAF-68 and PAF-72. We are now attempting to obtain the authors' final research report along with a recent publication by Baguelin.

3. WORK PLANNED FOR NEXT MONTHS

The work items planned for the coming months include:

1) Retrieve and recalibrate all measurement devices of three earth pressure cells. Ascertain state of enlarged tip cell and evaluate whether it can be repaired.
2) Evaluate results of in situ horizontal stress measurement program at Sta. 246.
3) Continue internal report on laboratory test results on 1977 specimens of Boston Blue clay.
4) Continue evaluation of pressuremeter test data and obtain undrained shear strength and undrained modulus from pressuremeter stress-strain curves.

5) Compare PAFSOR and Camkometer test results.
6) Prepare draft of final research report .

TABLE 1: WORK TASKS AND SCHEDULE
(revised 7/78)

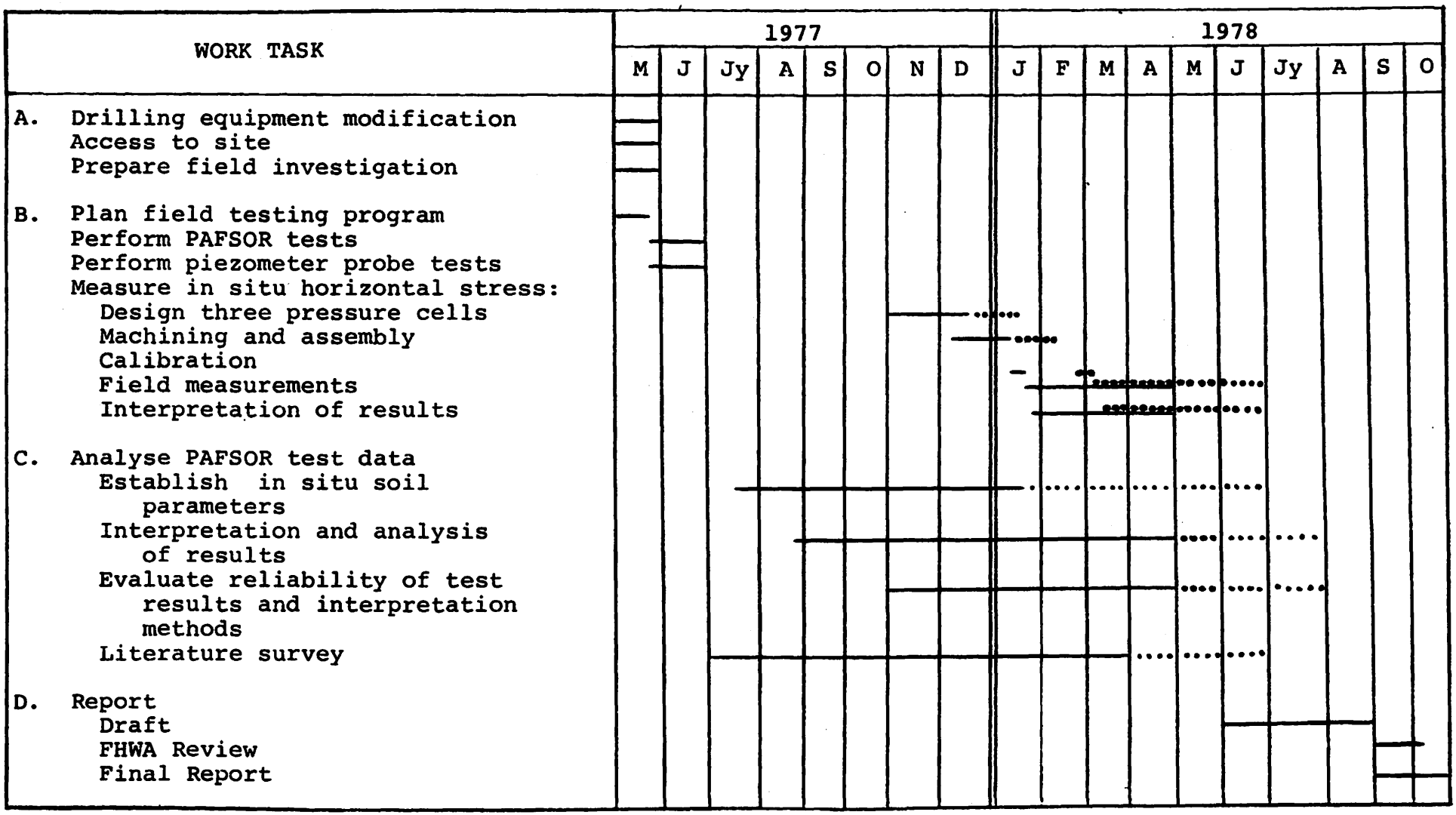

TABLE 2. PRINCIPAL ACTIVITIES DURING JULY 1978

Task B: Measurement of In Situ Horizontal Stress

1) Monitor performance of three earth pressure cells at Sta. 246 and reduce field data.

Task C: Interpretation of PAFSOR Tests

Establishment of In Situ Parameters

Review Boston Blue clay field vane, Dutch cone and SHANSEP strengths at I-95 and obtain profile of "in situ" undrained shear strength. This "final" s_u versus elevation variation is consistent with most strength data, model footing tests and the embankment failure case study.

Interpretation and Analysis of Pressuremeter Data

1) Reduce PAFSOR Tests at Sta. 246 to obtain the parameters s_u, P_1, and E_{50} using five different starting points on the P-ΔV curves (start of test, inflection point, extended inflection point, and lower and upper limits of best estimated σ_{ho}).
2) Analyze the sensitivity of each parameter in terms of the initial point of the test.

Literature Survey

Review Mr. Bennett John's report on use of pressuremeter test in U.S.A.

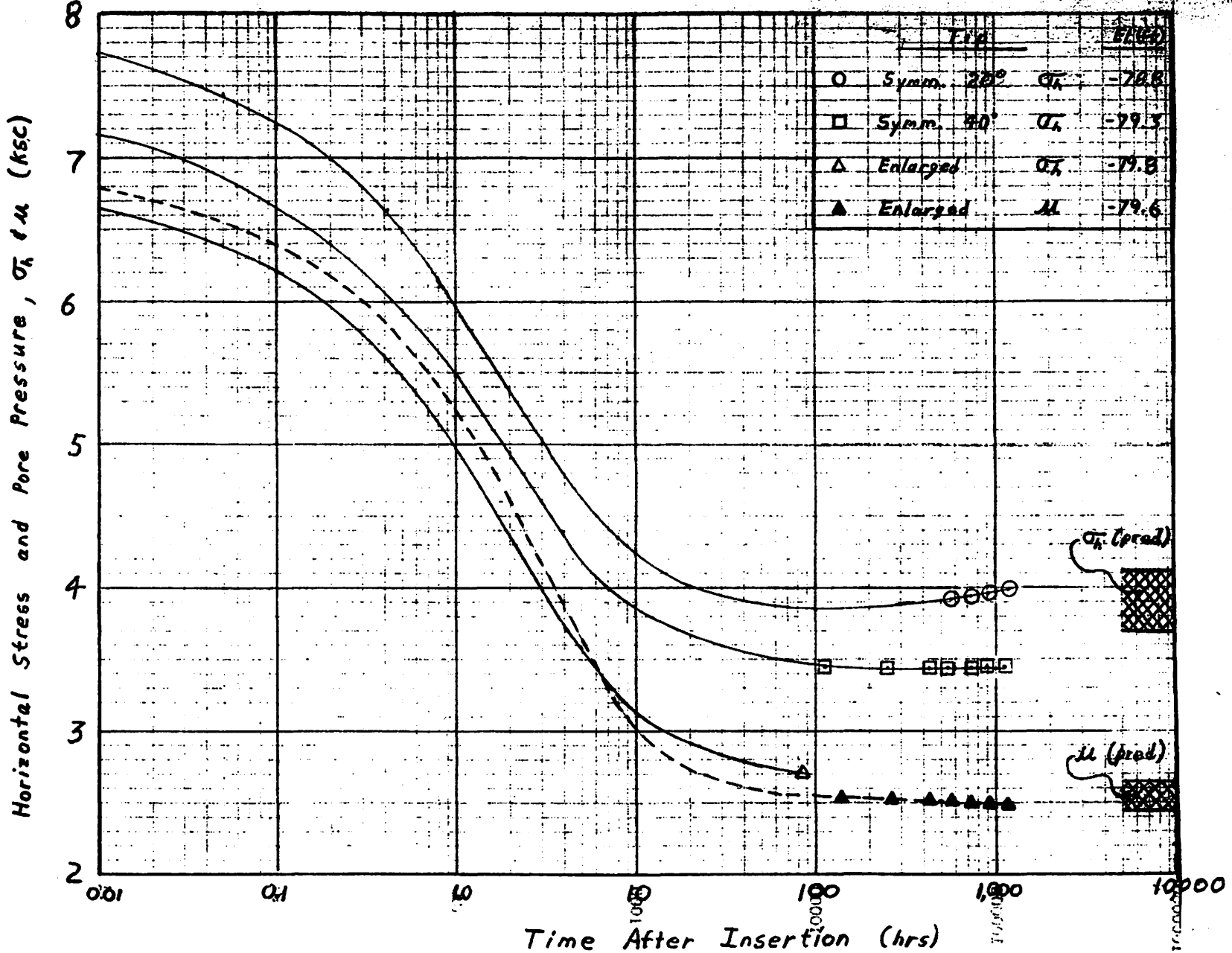

Figure 1

TOTAL HORIZONTAL STRESS AND PORE PRESSURE EQUILIBRATION

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rev. 6/18/78
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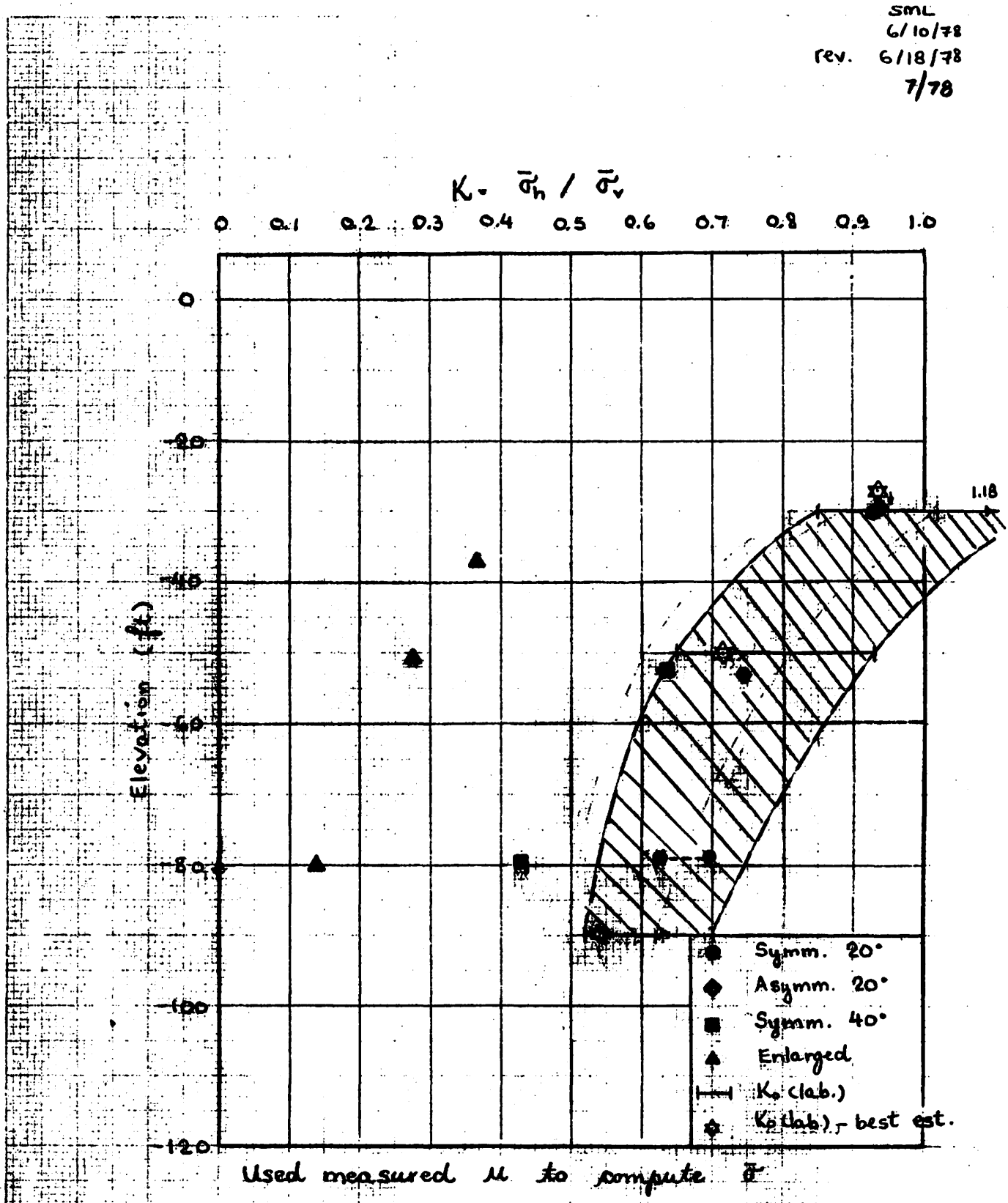

Used measured μ to compute $\bar{\sigma}$

COEFFICIENT OF EARTH PRESSURE
AT STA. 246

Figure 2

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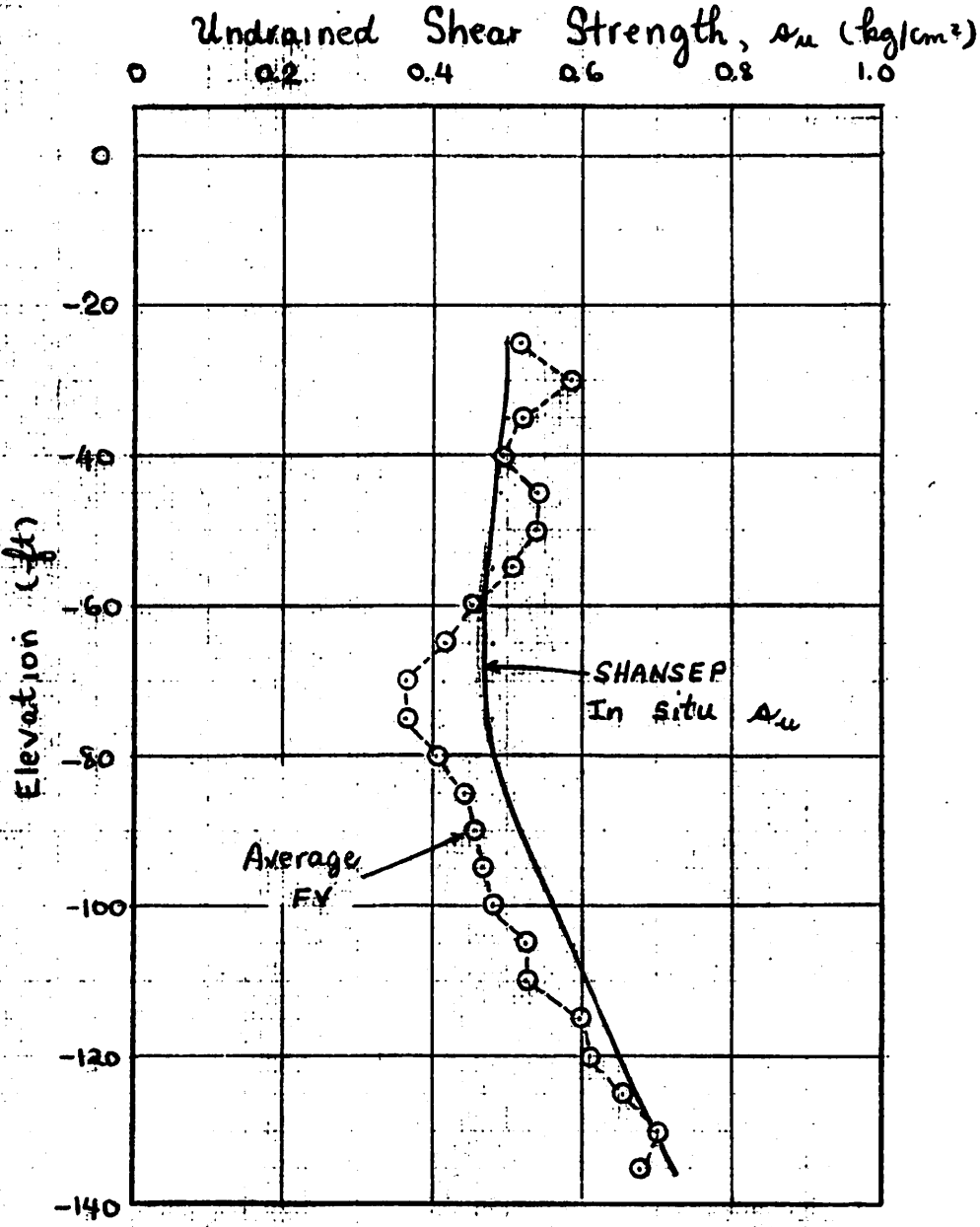
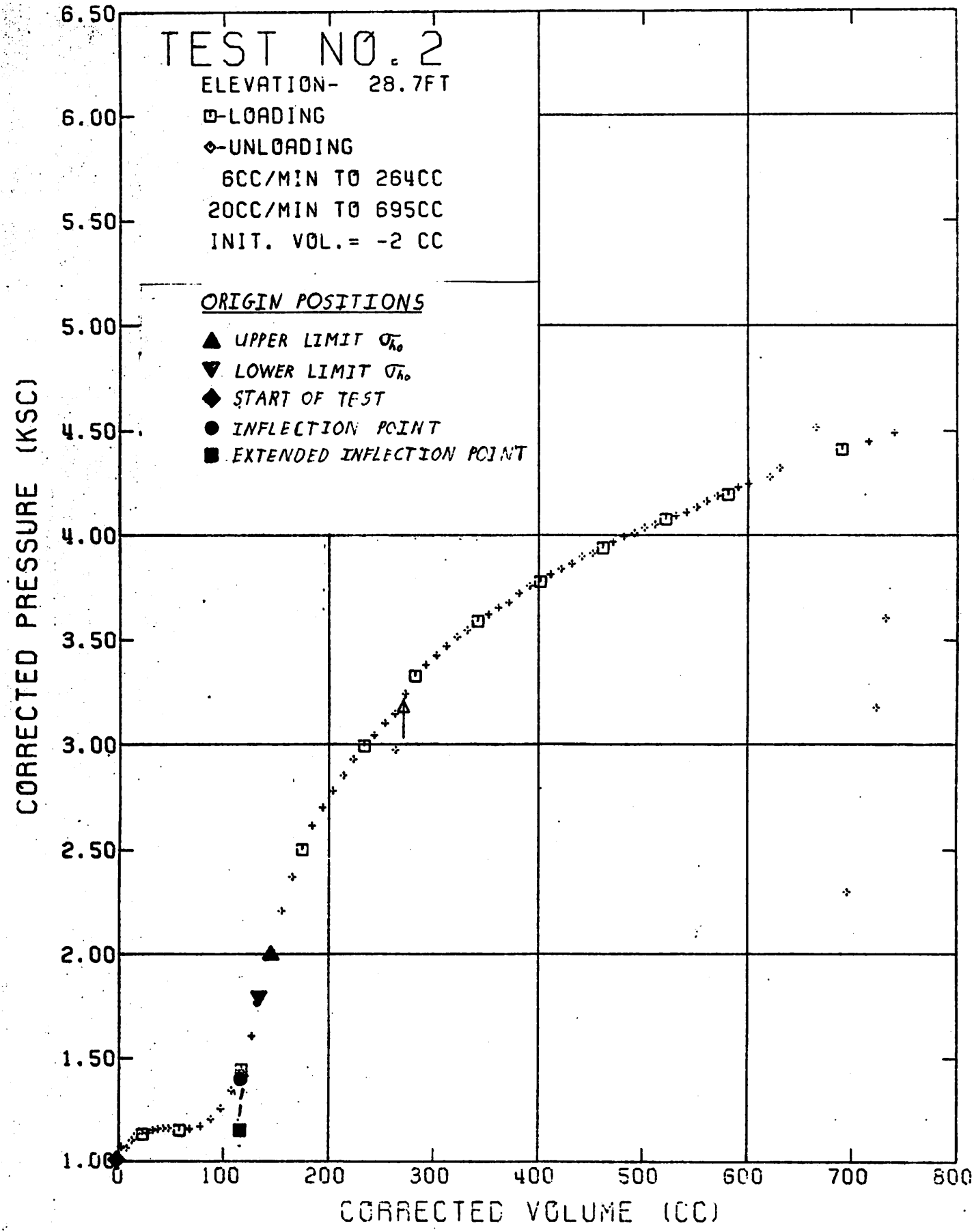


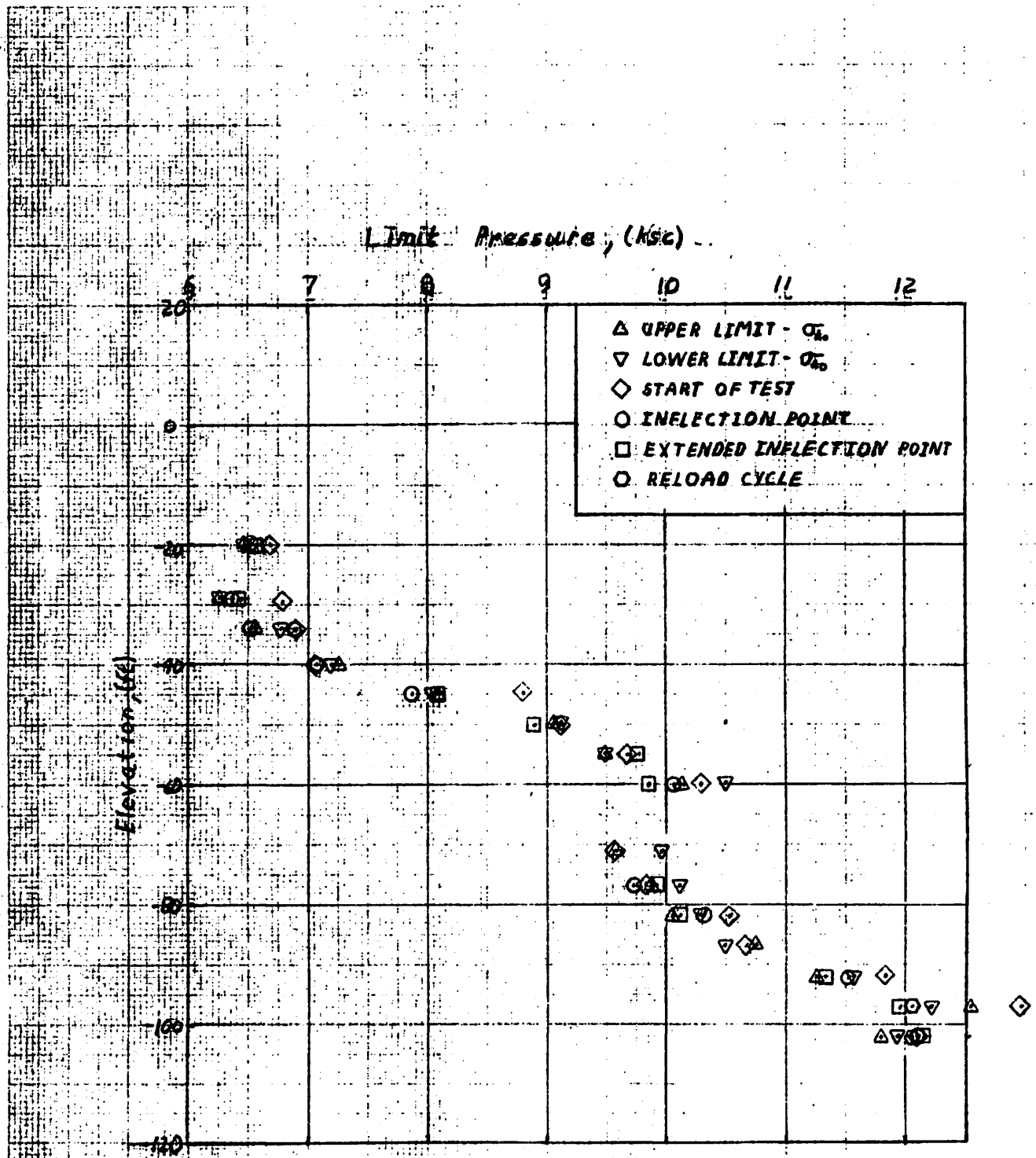
IN SITU UNDRAINED SHEAR STRENGTH OF BOSTON BLUE CLAY AT STA. 246

Figure 3



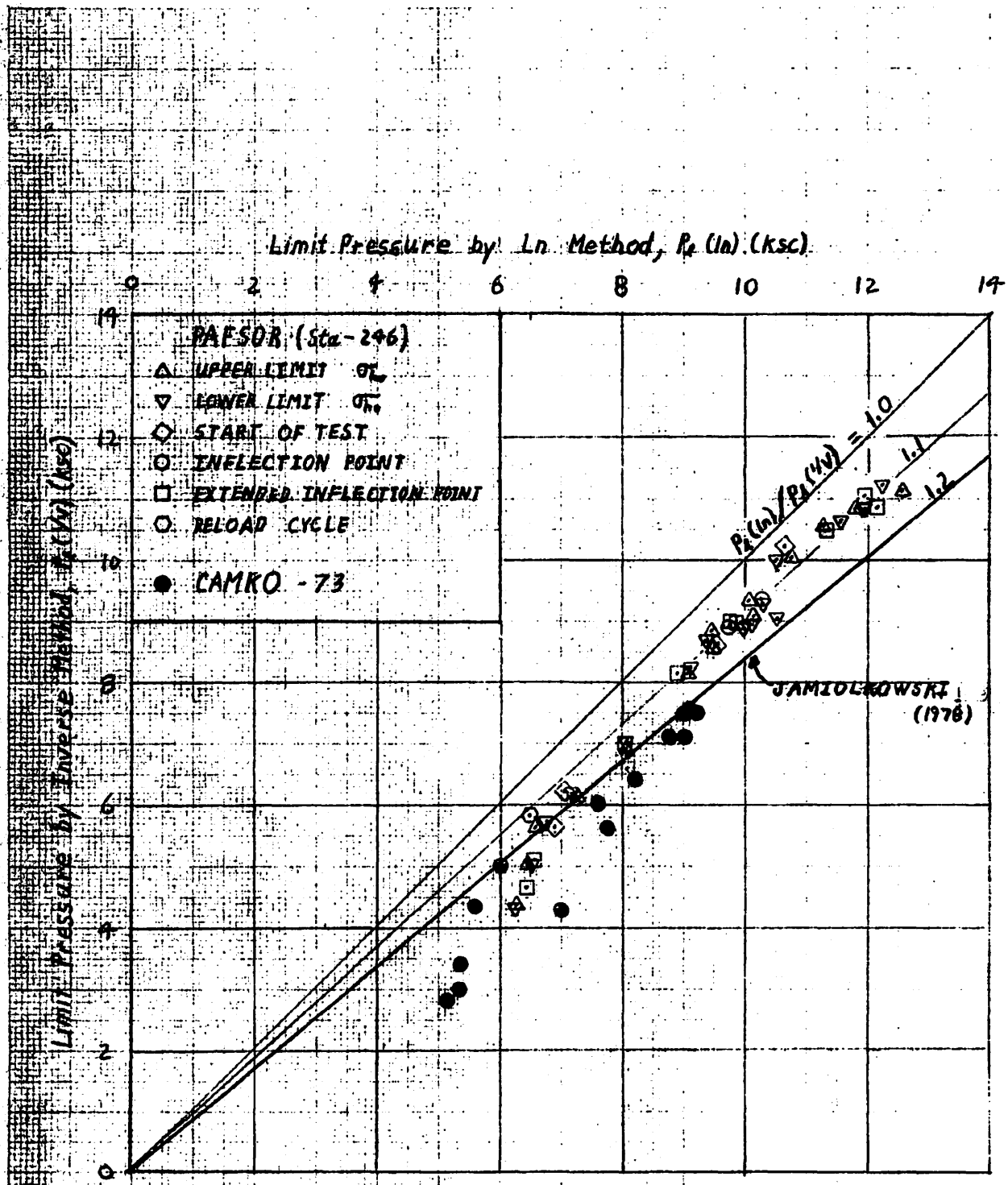
POSSIBLE ORIGINS TO ANALIZE PAFSOR TEST

Figure 4



LIMIT PRESSURE DETERMINED FROM LN METHOD
FOR PAPSOR TESTS AT STA. 246

Figure 5



COMPARISON OF LN AND INVERSE VOLUME LIMIT PRESSURES FROM PAFSOR AND CAMKO TESTS

Figure 6

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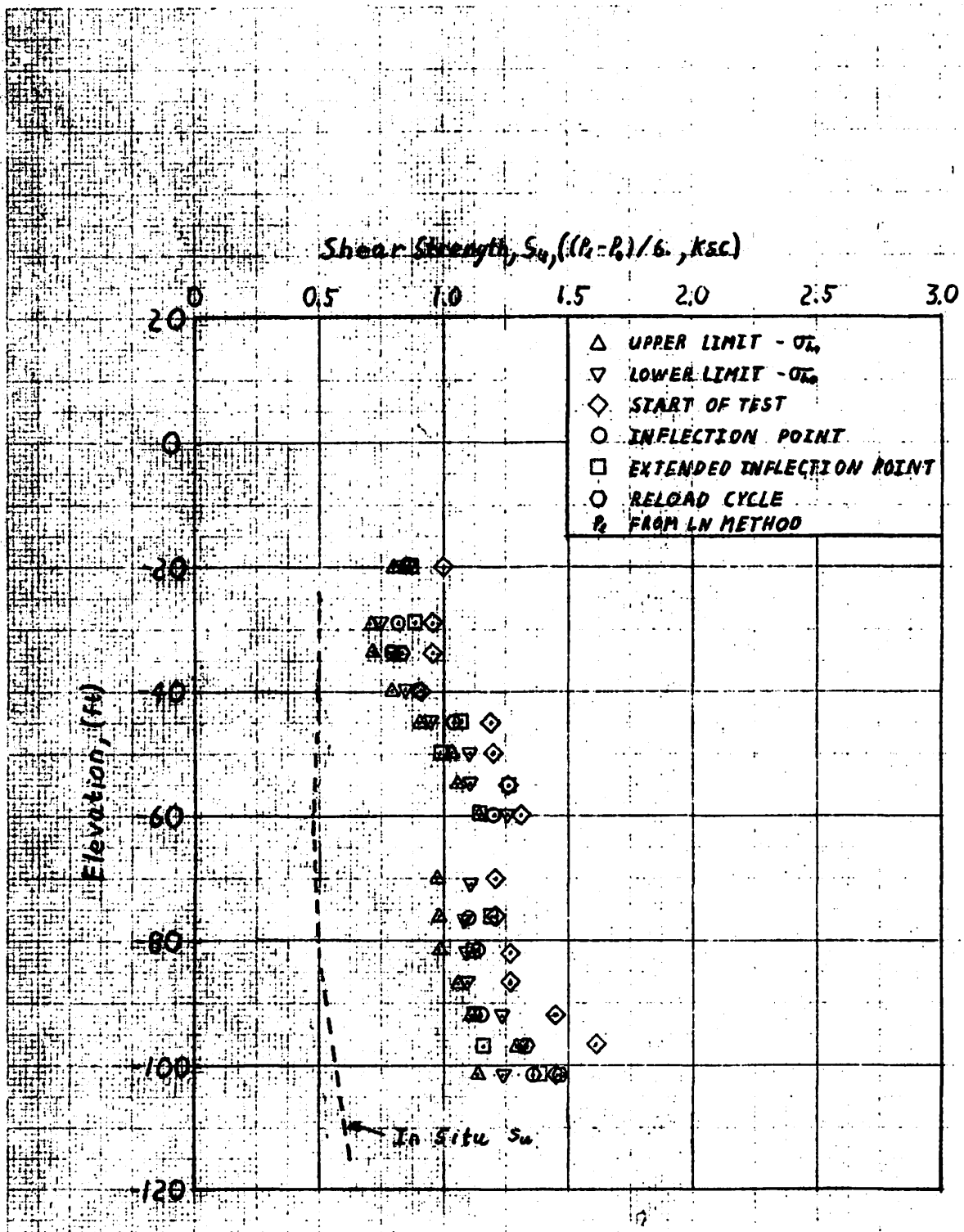
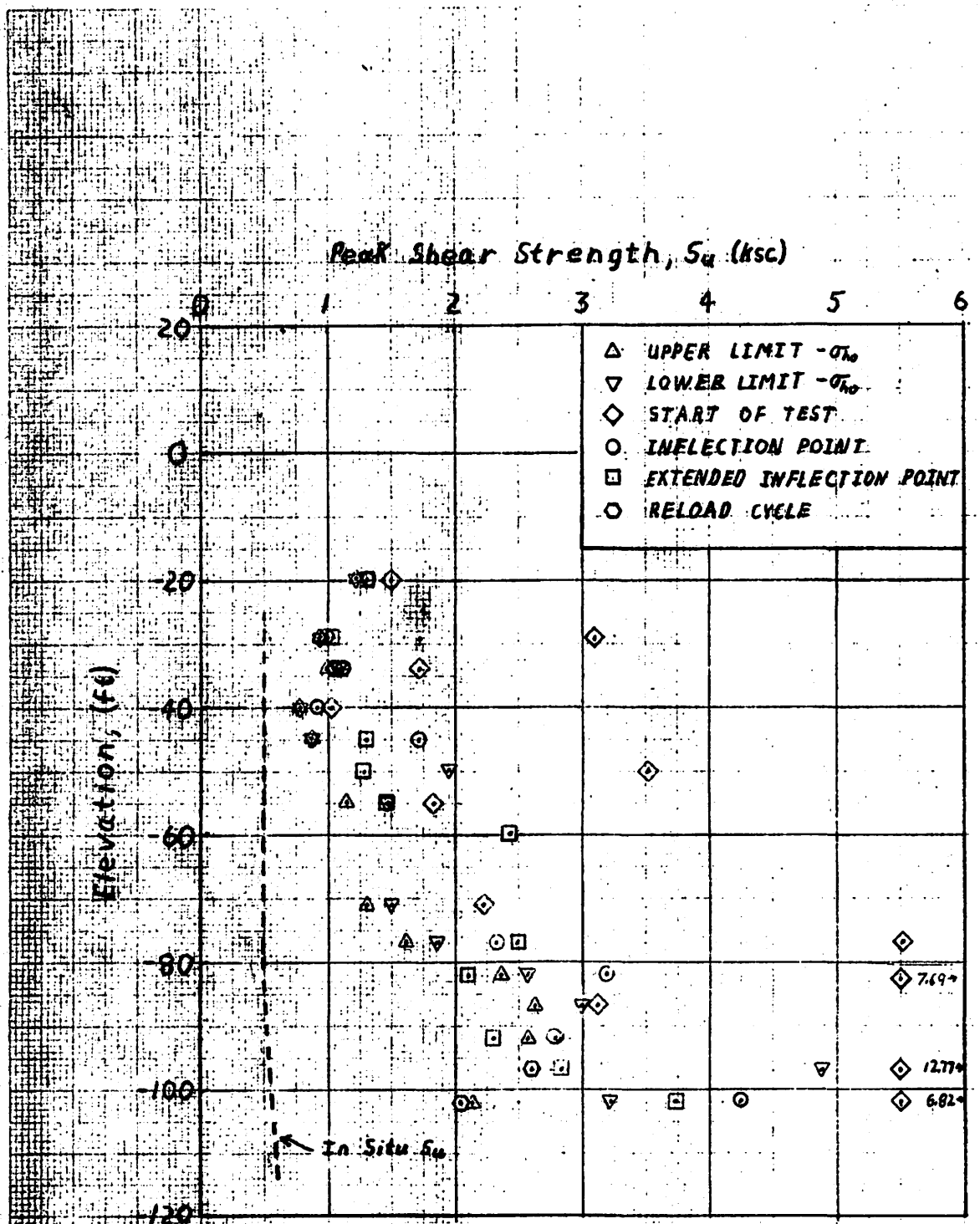


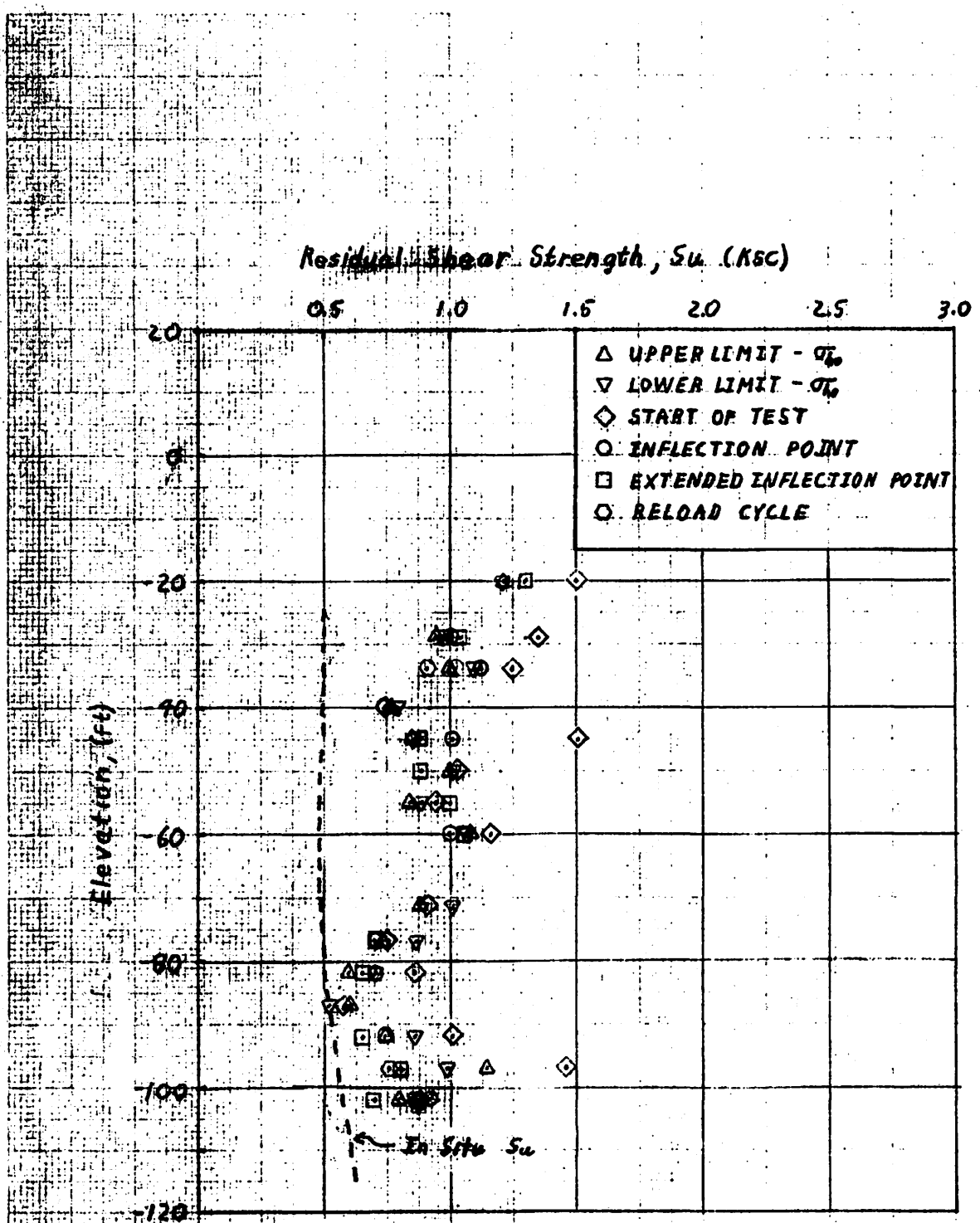
SHEAR STRENGTH FROM LIMIT PRESSURE
FROM PAFSOR TESTS AT STA. 246

Figure 7



PEAK SHEAR STRENGTH BASED ON LN PLOT
FROM PAFSOR TESTS AT STA. 246

Figure 8



RESIDUAL SHEAR STRENGTH BASED ON LN PLOT
FROM RAFSOR TESTS AT STA. 246

Figure 9

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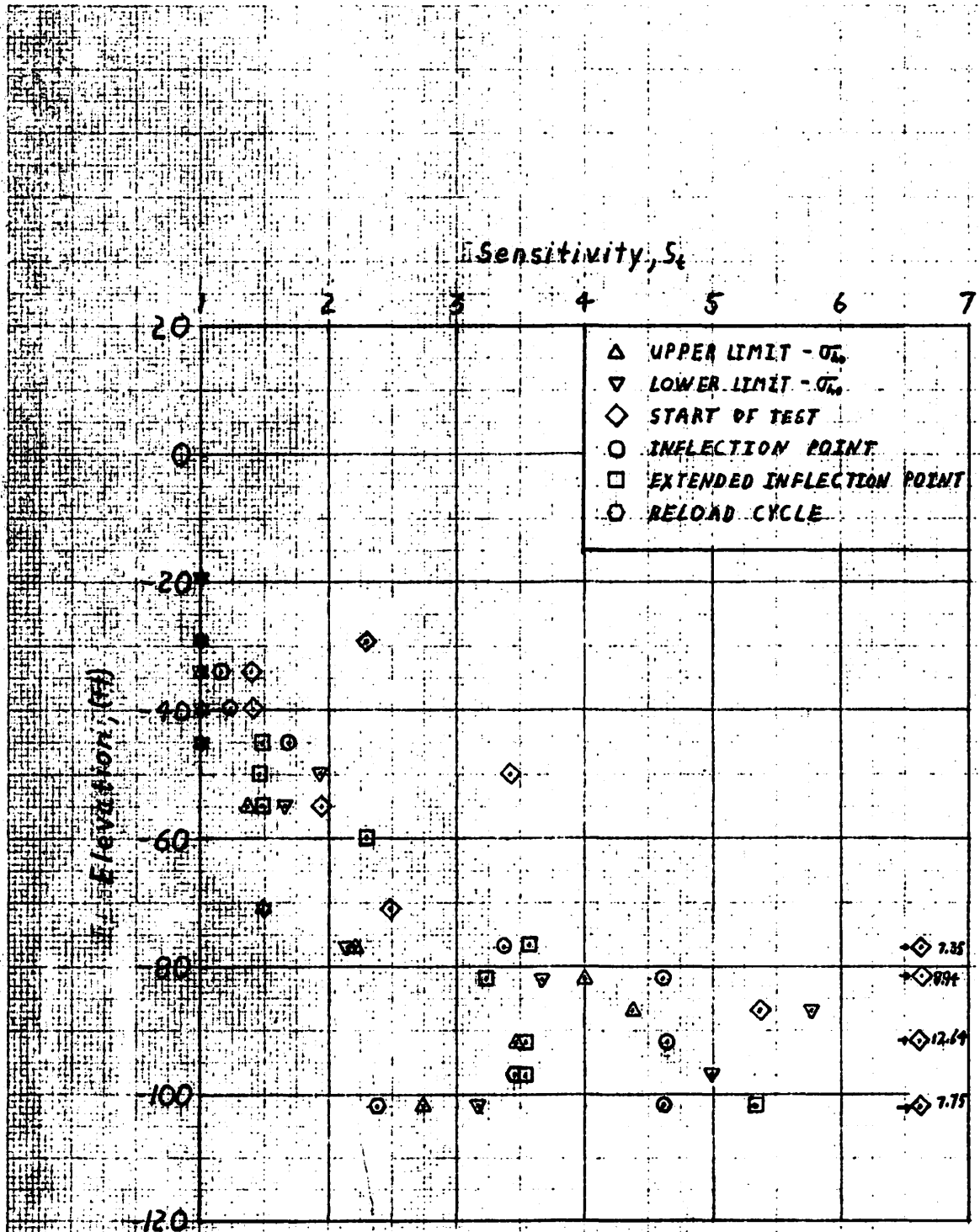

SENSITIVITY BASED ON LN PLOT
FROM PAFSOR TESTS AT STA. 246

Figure 10

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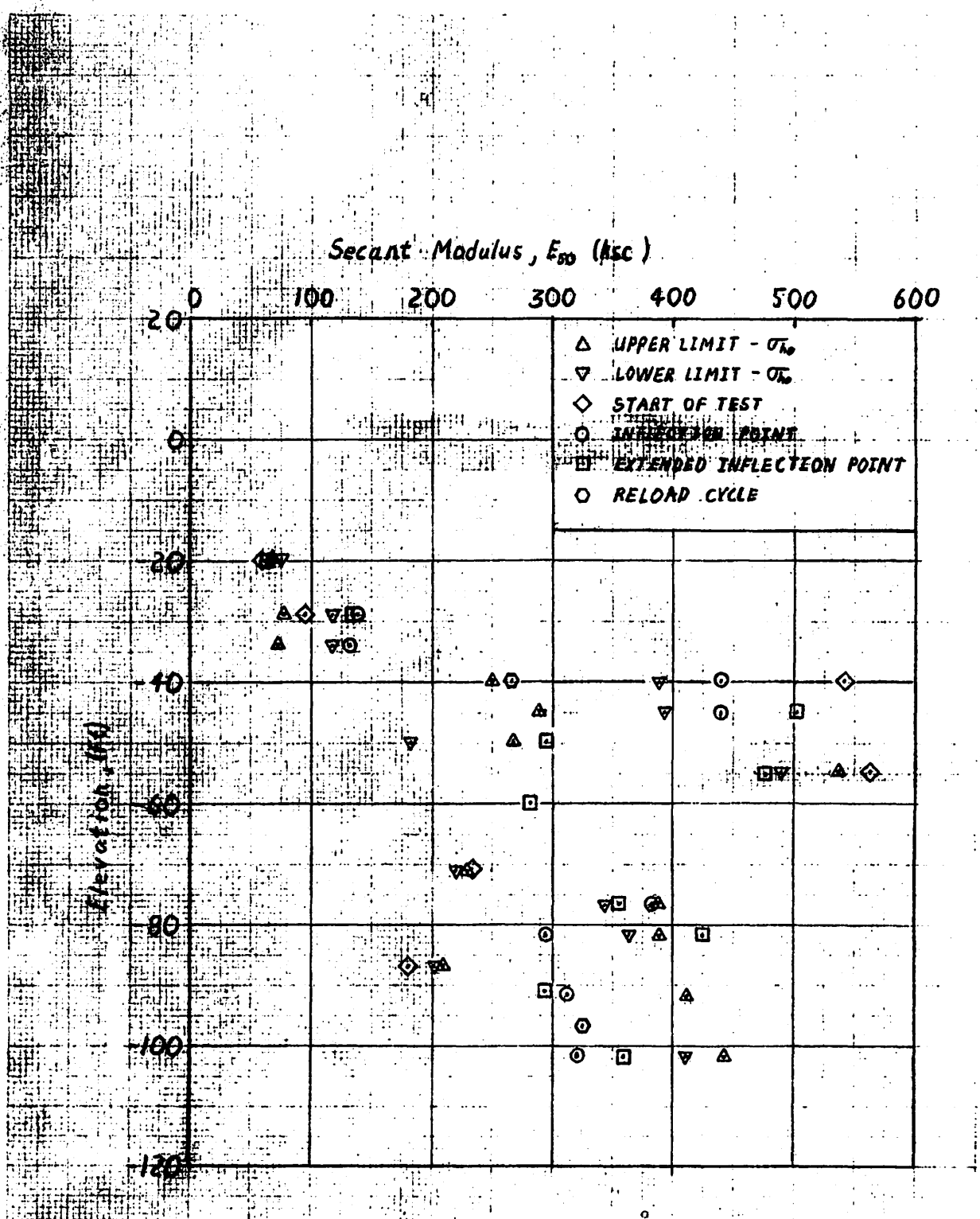

SECANT MODULUS BASED ON SUBTANGENT
FROM PAFSOR TESTS AT STA. 246

Figure 11